CHAPTER 5 – PROBLEMS

1. A water pump increases the water pressure from 10 psia to 50 psia at a temperature of 70 °F. What is the specific flow work of the water entering this pump? (0.0297 Btu/lbm)

2. Air enters a compressor at 100 kPa, 27 °C. What is the specific flow work of this air?

3. A steady-flow compressor compresses helium from 15 psia, 70 °F at the inlet to 200 psia, 600 °F at the outlet. The outlet area and velocity are 0.01 ft² and 100 ft/s and the inlet velocity is 50 ft/s. What is the mass flow rate and inlet area of this system?

4. Air is expanded from 1 MPa, 600 °C at the inlet of a steady-flow turbine to 100 kPa, 200 °C at the outlet. The inlet area and velocity are 0.1 m² and 30 m/s, and the outlet velocity is 10 m/s. What is the mass flow rate and outlet area of this system?

5. R-134a is expanded, while the entropy does not change, from 800 kPa, 60 °C at the inlet of a steady flow turbine to 100 kPa at the outlet. The outlet area is 1 m² and the inlet area is 0.5 m². Calculate the inlet and outlet velocities when the mass flow rate is 0.5 kg/s. (0.0299 m/s, 0.1093 m/s)

6. Water enters the 130 mm-diameter tubes of a boiler at 6 MPa, 65 °C and leaves at 5 MPa, 440 °C with a velocity of 80 m/s. Calculate the velocity and volumetric flow rate at the inlet to the boiler tubes.

7. Cyclone separators are used to remove fine solid particles that are suspended in a gas stream. In the flue gas system of an electrical power plant, the weight fraction of the fly ash is 0.001. What are the flow rates of fly ash and flue gas leaving a cyclone separator when the flow rate at the inlet is 10 lbm/s of flue gas and fly ash? (0.01 lbm/s, 9.99 lbm/s)

8. An air compressor compresses 10 liters/s of air at 120 kPa, 20 °C to 1 MPa, 300 °C and uses 4500 watts of electrical power. How much of this power is being used to increase the pressure of the air versus the power needed to move the air through the compressor?

9. An isobaric R-134a vapor separation unit separates the liquid and vapor portions of a liquid-vapor mixture into two separate streams. What is the flow power required to pass 3 liters/s of R-134a entering this separator at 200 kPa with 70% quality? What is the mass flow rate of the two exiting streams? (0 kW, 0.1323 kg/s, 0.3083 kg/s)

10. The mass flow rate of a compressed air line is divided into two equal streams by a 1 in-diameter T-fitting. The compressed air enters this fitting at 200 psia, 100 °F with a velocity of 150 ft/s. At both outlets, the compressed air state is 180 psia, 95 °F. What is the velocity of the air at the outlets and the flow power required for this fitting?

11. An adiabatic, steady-flow air compressor compresses 10 liters/s of air at 120 kPa, 20 °C to 1 MPa, 300 °C. How much power does this compressor require? (4.01 kW)

12. An adiabatic, steady-flow gas turbine expands air at 1000 kPa, 500 °C to 100 kPa, 150 °C. The air enters the turbine through a 0.2 m² opening with a velocity of 40
m/s and exhausts through a 1 m² opening. What is the mass flow rate and power production of this turbine?

13. As an automobile moves through the air, the air velocity (measured with respect to the automobile) decreases as the effective flow area increases. An automobile whose effective flow channel is 30 ft² is traveling at 60 miles per hour on a day when the barometric pressure is 30 inches of mercury and the temperature is 80 °F. Behind the car, the air velocity is measured as 55 mph and the temperature as 80 °F. Determine the effective flow area behind the car and the power required to move this car through the air. (32.73 ft², 6.5 hp)

14. An adiabatic air compressor compresses air from 15 psia, 70 °F to 300 psia, 800 °F. It enters the compressor through a 1.5 ft² opening with a velocity of 100 ft/s. It exits through a 0.8 ft² opening. Calculate the compressor mass flow rate and specific work consumption.

15. A steam turbine operates with 1.5 MPa, 360 °C steam at its entrance and 30 °C saturated steam vapor at its exit. The mass flow rate of this steam is 30 kg/s and the turbine produces 15 MW of power. What is the rate at which heat is lost to the environment through the turbine's insulation?

16. Saturated liquid water is heated in a steady-flow steam boiler at a constant pressure of 800 psia. No shaft work is required for this process. How much heat is required per pound-mass of steam passing through the boiler when the outlet temperature is 600 °F.

17. A 110 volt electrical heater is used to warm 3 ft³/s of air at 14.7 psia, 65 °F to 14.7 psia, 85 °F. What is the current passing through this electrical heater? (10.4 amps)

18. A 110 volt electric hot water heater warms 0.1 liters/s of atmospheric pressure water at 15 °C to 20 °C. How much current does this heater require?

19. Steam enters a long, insulated pipe at 1.5 MPa, 360 °C with a velocity of 20 m/s, and leaves at 1 MPa, 360°C. The pipe diameter at the entrance is 0.15 m and it is 0.1 m at the exit. Calculate the steam mass flow rate and the steam velocity at the outlet. (1.87 kg/s, 68 m/s)

20. A portion of the steam passing through a well insulated (i.e., constant entropy) steam turbine is sometimes removed for the purposes of feedwater heating. Consider such a turbine with steam entering it at 12 MPa, 560 °C with a mass flow rate of 20 kg/s, bleed stream is removed at 1 MPa, 200 °C with a mass flow rate of 1 kg/s, and the remaining steam is exhausted at 100 kPa as a saturated vapor. How much power does this turbine produce?

21. The stators in a gas turbine are designed to adiabatically (i.e., constant entropy) increase the kinetic energy of the gas passing through them without any shaft work or change in area. Air enters a set of stators at 300 psia, 700 °F with a velocity of 80 ft/s and leaves at 250 psia, 645 °F. What is the air velocity at the exit of this stator?

22. The diffuser in a supersonic jet aircraft is a passage designed to reduce the velocity of the air passing through it without any heat (i.e., constant entropy) or work transfer. What is the velocity of the air leaving a diffuser when air enters it at 15 psia, 70 °F with a velocity of 1500 ft/s and leaves at 30 psia, 210 °F?
23. Air is expanded in an adiabatic nozzle by a reversible, polytropic process with \( n = 1.3 \). It enters the nozzle at 100 psia, 200 °F with a velocity of 100 ft/s and exits at 25 psia. What is the temperature and velocity of the exiting air? \((479 °R, 1477 \text{ ft/s})\)

24. Wet steam in a steam line at 2 MPa is throttled to 100 kPa, 120 °C. What is the quality in the steam line?

25. A small position control rocket on a satellite is driven by a 2 ft\(^3\) container filled with R-134a at -10 °F. Upon launch, this container is completely filled with saturated liquid R-134a. This control rocket is designed for short bursts of 5 s duration. During each burst, the mass flow rate leaving the rocket is 0.06 lbm/s. How many such bursts can this rocket undergo before the quality inside the container is 90% or more presuming that the temperature of the R-134a is maintained at -10 °F? \((680)\)

26. A pneumatic accumulator, arranged to maintain a constant pressure as air enters or leaves it, is set for 200 psia. Initially, the volume of this accumulator is 0.2 ft\(^3\) and the air temperature is 80 °F. Air is now added to the accumulator until the volume is 1 ft\(^3\) and the temperature is 80 °F. How much air has been added to the accumulator?

27. A rigid container originally filled with an ideal gas is heated while gas is released in such a manner that the temperature of the remaining gas remains constant. Derive an expression for the gas mass flow rate at the container outlet as a function of the rate of pressure change in the container. \([-\frac{V}{RT})(\frac{dP}{dt})]\)

28. A 2 ft\(^3\) scuba diver's tank is to be filled with air from a compressed air line that remains at 120 psia, 100 °F. Initially, the air in this tank is at 20 psia, 70 °F. Presuming that this tank is well insulated, determine the air temperature and mass in the tank when it is filled to 120 psia.

29. Oxygen is supplied to a medical facility from 10-3 ft\(^3\) compressed oxygen tanks. Initially these tanks are at 2000 psia, 80 °F. After two weeks of use, the remaining oxygen is at 100 psia, 80 °F. What is the total mass of the oxygen used and the amount of heat transfer between the tanks and their surroundings? \((314.8 \text{ lbm}, 10,600 \text{ BTU})\)

30. Two 10 ft\(^3\) adiabatic, rigid tanks are connected by a valve. Initially, one tank contains water at 450 psia, 10% quality while the second contains water at 15 psia, 75% quality. The valve is now opened and the pressure becomes the same in both tanks. What is the final pressure and mass in the tanks?